Market Uptake of Solar Thermal
Electricity through Cooperation

Geopolitics and energy security of CSP deployment for domestic use and intra-European trade in the time of COVID-19

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Market Uptake of Solar Thermal Electricity

About the Project

In the light of the EU 2030 Climate and Energy framework, ***MUSTEC- Market uptake of Solar Thermal Electricity through Cooperation*** aims to explore and propose concrete solutions to overcome the various factors that hinder the ***deployment*** of concentrated solar power ***(CSP)*** projects in Southern Europe capable of supplying renewable electricity on demand to Central and Northern European countries. To do so, the project will analyse the ***drivers and barriers*** to CSP deployment and renewable energy (RE) cooperation in Europe, identify future CSP ***cooperation opportunities*** and will propose a set of concrete ***measures*** to ***unlock the existing potential***. To achieve these objectives, MUSTEC will build on the experience and knowledge generated around the cooperation mechanisms and CSP industry developments building on concrete CSP ***case studies***. Thereby we will consider the present and future European energy market design and policies as well as the value of CSP at electricity markets and related economic and environmental benefits. In this respect, MUSTEC combines a dedicated, comprehensive and multi-disciplinary analysis of past, present and future CSP cooperation opportunities with a constant ***engagement*** and ***consultation*** with ***policy makers*** and ***market participants***. This will be achieved through an intense and continuous ***stakeholder dialogue*** and by establishing a tailor-made ***knowledge sharing network***.

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1 INTRODUCTION

The European electricity system is changing rapidly. The share of renewable power has doubled in the last 15 years (Eurostat 2019, Agora Energiewende and Sandbag 2020), and both the European Commission and an increasing number of Member States have set targets of 100% renewable power by 2050 or before (Lilliestam et al. 2019b). Such targets are highly challenging, but there is increasing evidence that it is both technically possible and economically attractive: numerous analyses, in MUSTEC (Schöniger et al. 2020) and outside (e.g. (Bogdanov et al. 2019, Tröndle et al. 2019, Tröndle 2020)), have shown that the potential for 100% renewable is sufficient and that the cost of fully renewable power systems can be comparable or lower than today's cost. Politically, the energy transition may be even more difficult than on the techno-economic level. At the centre of the energy transition stands policy, certainly as the prime mover of the transition (e.g. through support policies) but also as an object affected by the transition: as the energy system transforms, existing (power) structures change, new opportunities and necessities arise and old truths lose validity (Schmidt and Sewerin 2017, Meckling 2018).

With the transition, the status quo in the classical energy policy fields of energy security and geopolitics is upset. These policy issues are central to national economies, and are central pillars for national security. Without reliable electricity supply, modern economies will likely collapse and with them, entire nations may fail (Cherp and Jewell 2011, Cherp and Jewell 2014). In terms of energy security, a system based on fluctuating renewables is very different than one built on fully dispatchable fossil fuels. Such technical implications are severe, and although there are ways to design a renewable power system to be stable even during extreme conditions – full stability at all times is a hard boundary condition of fully renewable power scenarios, also in MUSTEC – the nature of energy security and how it is handled will be entirely different in a renewable power future compared to today. That then has implications for the political attractiveness – the legitimacy – of fully renewable power systems: that such a system is technically secure does not necessarily mean that decision-makers are comfortable with the outlook of their national economy and security being dependent on the current weather. Concentrating solar power (CSP) as one of the few scalable and fully dispatchable renewable electricity sources in Europe, may have a critical role to play to balance fluctuating renewables and ensure power system stability in a way similar to how fossil fuels perform this task today.

Geopolitics of energy has historically been a driver of energy policy, both over control of resources and of the values created in the energy industry. Consequentially, it also been a source of conflict, within and between countries; the political memories of the "energy weapon" as wielded by Arab countries in the Yom Kippur War in 1973 or in the Russian-Ukrainian gas conflict in 2006-2009 remain strong. Renewables are entirely different than fossil energy regarding their geopolitical implications, as a renewable power system does not rely on energy imports from potentially unreliable states. With the rise of renewables, the geopolitics of energy will change, and instead of resource-endowed countries, technological leaders will be the geopolitical centres of the future energy world – and currently, Europe is a technology leader, although others, especially China, have caught up quickly. In a renewable future, Europe may produce the technology it needs domestically, reducing its dependence on other countries, and possibly creating substantial growth and jobs in new, future-proof green industries. Geopolitically, CSP may have an important role to play for Europe, both by enabling stable operation of the power system also with very high shares of renewables and by contributing to European integration through renewable power cooperation.

Currently, European and Member State politics is in flux, triggered by the massive social and economic effects of the COVID-19 crisis. As countries shut down, and borders and companies and closed, the deepest recession in post-war Europe started, triggering the largest economic stimulus action ever seen. As most European countries, including Spain, and the European Commission seem intent to spend large shares of these recovery funds on green growth and pushing the European renewables and climate agendas, renewable power may be one of the winning sectors in the crisis: after an initial crunch, it seems likely that renewables will be a key part of the trillion-Euro recovery schemes in Europe. As CSP is still a mainly European industry, spending in the CSP sector may have the multiple benefits of securing our electricity stability and creating new jobs in a future-proof industry.

The outbreak of COVID-19 has completely changed the European Union's internal geopolitical landscape, including in the energy domain. The political and economic consequences of the COVID-19 pandemic has made internal geopolitical and geo-economic drivers even more relevant than before. Countries like Italy and Spain are expected to be among the most affected, having the higher death tolls and the biggest economic and social costs, which risks exacerbating populist and nationalist movements and political parties. Anti-EU feelings and a North-South political divide risk to re-emerge and intensify, re-opening the wounds of the financial crisis. Because the COVID-19 crisis implies a significant shift in the EU's geopolitical and energy geopolitics' landscape, the scope of this deliverable has been expanded to reflect the new context.

In this report, we focus on the hard politics of CSP and CSP cooperation: on geopolitics and on energy security. We focus on both the (geo)political reasons for CSP and reasons for the absence of CSP on the European and national geopolitical agendas (section 2), and the effects of CSP deployment and CSP cooperation on European energy security (section 3). Finally, we discuss the implications of the findings regarding geopolitics and energy security on the possibility to include CSP in Europan Corona recovery plans and the Green Deal (section 4). In all sections, we focus both on the European level, and zoom in on Spain where appropriate, as this is the Member State at the centre of CSP considerations in Europe. The deliverable concludes that mainstreaming and fast-tracking CSP cooperation mechanisms benefits southern Member States and constitute a consistent EU geopolitical response to the COVID-19 crisis.

Policies needed for deploying CSP are discussed in other deliverables in MUSTEC, especially in Deliverable 7.4 (Schöniger et al. 2020) and Deliverable 10.1 (Boie and Franke 2020), and in the upcoming MUSTEC roadmap (Deliverable 10.3, forthcoming). D.6.4 already identified the geopolitical and geo-economic benefits of increasing the integration of CSP and renewables' exchange and cooperation mechanisms: increasing energy security, fostering intra-European functional electricity integration, and providing economic opportunities to Southern EU MS with solar resources and CSP capabilities. The latter would allow Mediterranean MS having suffered the most from the financial crisis to benefit from their comparative advantages while contributing to the EU's energy security and its compliance with emission reduction and renewable targets. Here, we focus on these two classical areas of energy policy analysis, investigating how CSP deployment in southern Europe – both for domestic supply and intra-European "export" through cooperation – affects energy security and geopolitics in Europe.

2 The geopolitical role for CSP and cooperation mechanisms in a fully renewable European power system

In the MUSTEC project's deliverable 6.4 (Escribano et al. 2019) on the geopolitical context for CSP in Europe, we analysed the key academic, strategic and think tank literature in order to try to assess the geopolitical role for CSP cooperation mechanisms in the EU and carried out a set of elite interviews. The results of the geopolitical analysis stand in contrast to the other results from MUSTEC: whereas other MUSTEC outputs found a potential geopolitical and geo-economic value in CSP cooperation mechanisms, Escribano et al. (2019) showed that if a potential geopolitical and geo-economic value for CSP exists, it has not materialised in policymakers' narrative or actions, nor had it been broadly recognized in the literature. This is similar to the finding of Lilliestam et al. (2019b), who showed that CSP is a non-issue in renewable energy and climate policy in most European countries.

In this section, we summarise the insights from the MUSTEC work on geopolitics for CSP and cooperation mechanisms, through a literature review and by drawing further conclusions from the interview work carried out in the project.

2.1 Literature review

The literature review concluded, first, that renewables in general are a source of "soft power" (Nye, 2004), especially for the EU. Escribano et al. (2019) refers to the original concept of "soft power" *à la* Nye: the influence that is exerted by example, proposing energy models that appeal to other countries because of their contribution to global or regional public goods while constituting economically and socially attractive energy pathways. In a similar manner, promoting renewables to achieve a European green economy would enhance the EU's power base and role in future climate geopolitics (Oberthür, 2016). For the purposes of the MUSTEC project, Escribano et al. (2019) concluded that the soft power attached to renewables constitutes an opportunity for a more attractive narrative highlighting the geopolitical externalities of intra-EU renewable exchanges.

Second, the strategic significance of storage and dispatchability in "grid communities" is one of the most relevant geopolitical drivers for CSP. According to Scholten and Bosman (2016), in a 100% renewable electrified energy system, countries would have to opt for a national model based upon distributed generation; or, alternatively, for a centralized continental network (a "grid community") implying greater strategic influence for those countries able to make the most of their geographical comparative advantages to control the grid, taking on management, transport, balance, storage and/or surplus generation capacity. This means a shift from geopolitics based on controlling resources to geopolitics based on grid management and balancing, as exemplified by Norway's strategic repositioning from gas supplier to capacity companion of the European Union's energy transition (Gullberg, 2013).

Nevertheless, in integrating electricity markets, independently of whether electricity is renewable or not, the different countries' perspectives on energy security, the role the interconnectors plays in their energy policies, their mutual perceptions and the foreign policy and trade context of the interconnector have to be taken into account (Puka and Szulecki, 2014). Fischhendler *et al*. (2016) suggest that geopolitical uncertainties influence the choice between self-reliance, coexistence and integrated borders. They identify four different types of geopolitical bottlenecks hindering the emergence of "grid communities": zero-sum game strategies, grid dependency aversion, lack of trust, and an energy security-economy dilemma by which some countries prefer self-sufficiency rather than regional grid integration. Choosing a "grid community" implies the existence of integrated borders, while opting for national electricity systems signals a preference for self-reliance.

Focusing on CSP geopolitical drivers and barriers, the literature review found few references to this technology, and most refer to Desertec-related research. For instance, its vulnerability to terrorist attacks seems to be just as low as it is for gas (Lacher and Kumetat, 2011); And the mechanisms to stabilise the power system against other disturbances would in all but extreme attack scenarios suffice to maintain system stability also if trade lines were attacked by terrorists (Lilliestam, 2014).

Regarding the potential emergence of a renewable resource curse, renewable technologies are supposed to be less prone both to conflict and to be used as a weapon (Overland, 2019), and CSP is no exception (in contrast with hydroelectricity mega-projects). Renewable income is generated by exploiting flows and not stocks, generation is spread and energy density low: if a PV farm is stopped in order to put pressure on a consumer, the producer loses income and delays the recovery of its investment; a CSP plant could do it only for some hours, reducing the geopolitical incentives and leverage to generate conflicts, either between States or at a domestic level.

Finally, the literature review showed that CSP it is almost absent from both the academic and the policy-oriented geopolitical energy landscape. Admittedly, several papers were devoted to Desertec and some of its criticalities, before and after its failure. Some others address institutional and political de-risking in Africa, which are not truly applicable to intra-EU cooperation (Papapostolou et al., 2016; Carafa et al., 2016; Labordena et al., 2017). The results of Escribano et al. (2019) highlight for the first time CSP's geopolitical externalities, like adding to the EU's "soft power", its storage capacities potentially contributing to articulate grid communities, and the associated geographic and technology portfolio diversification.

2.2 Interviews

In the context of the geopolitical analysis of MUSTEC, we carried out 11 elite interviews (3 in Germany, 4 in Italy and Spain; with think tankers and policy planners from the Ministries of Foreign Affairs and Defence). The purpose of these interviews was not to obtain answers from a representative population sample, but rather to analyse the views of well-informed and influential individuals in the energy and geopolitical landscape of the three selected EU Member States.

The interviews clearly show that neither EU's nor the Member States' energy security strategies include any structured strategic thinking regarding the geopolitical externalities of grid communities or their potential to enhance the EU's renewable soft power –and even less so in the case of cooperation mechanisms and CSP. The interviews did not deal exclusively with CSP and cooperation mechanisms, rather framing both issues within the broader energy geopolitics context. In fact, most interviewees found the specific questions on the geopolitics of CSP deployment and cooperation mechanisms difficult to answer, due to their lack of knowledge about this technology and its potential geopolitical externalities. It is then hardly surprising that the geopolitical implications of CSP have gone almost unnoticed.

When asked about the role that CSP currently plays or could play in the future within EU and Member States' external and energy security strategies, several answers were "none" (or “residual”) and “no idea”. An Italian respondent’s assessment was it to be a fringe issue: they saw potential in extra-EU CSP projects in North Africa but no particular geopolitical role today or in the future for intra-EU CSP exchanges beyond industrial promotion abroad. A German expert insisted on the “development cooperation” approach of the German government in Morocco, missing that narrative within the EU. Spanish analysts’ concern was that new technologies, like hydrogen or storage, could erode the geopolitical advantages of CSP.

When asked about country policy preferences regarding CSP deployment and CSP cooperation mechanisms, an Italian analyst perceived CSP as an “immature technology” that needs some form of support for early deployment. He also stated that if local players could make the case for CSP and its strategic storage function, there could be payments for flexibility and preferential financing mechanisms. More specifically, technological advances in storage capacity (beyond daily storage) were mentioned as a driver of future interest in CSP. Another analyst wondered why the CSP technology did not generate great enthusiasm in Italy compared to PV, doubting that the CSP industry could foster such a move. For Germany, the interest in CSP was mentioned with reference to industrial policy. The lack of a well organised lobby supporting CSP in Germany was additionally mentioned as a barrier for CSP deployment and CSP cooperation. Spanish analysts referred to technological and industrial drivers, but no geopolitical considerations regarding security of supply other than diversification and reducing imports. Finally, policy planners complain about the lack of information on CSP geopolitical virtues, as well as resistances to integrate “niche” technologies in strategic analyses.

As regards Member States’ interest in CSP cooperation mechanisms, the short answer in most cases was “none”. Spanish diplomats were aware of CSP mainly because of economic diplomacy reasons, while they were not familiar with EU renewable cooperation mechanisms. In general, diplomats tended to see both cooperation mechanisms and CSP, more than other renewables (wind and PV), an issue for the Energy Ministry. CSP is perceived by the international relations and geopolitics communities as highly technical, immature, high cost, with no evident strategic externalities (compared to future batteries, for instance), and in general at the lower end of low politics.

Trying to identify the likelihood of future CSP cooperation, elite interviewees were asked about the probability that their countries would want to participate in CSP cooperation mechanisms and with which countries. All interviewees thought it was very likely that their countries would participate in CSP cooperation mechanisms in the future, in spite of its benefits not being clearly established at present. Some Italian and Spanish analysts used the expression of being “followers” if the push comes from abroad (i.e. from the EU). However, no leadership on the issue was exerted from Brussels according to Member States’ perspective. Interviewees also claimed that a comprehensive strategic view on such a “novel” issue is still lacking.

Italy seemed more interested in a Southern European alliance with Portugal, Spain, France and perhaps Greece, as well as the Balkans and the Southern shore of the Mediterranean. CSP cooperation and exports to Germany were considered a second rank priority. A Spanish diplomat and a German analyst nuanced that the economics should be viable for both countries to support it. In Spain, propensity to cooperate with any Member State was higher, with France and Germany (for different reasons) ranking high; however, more pragmatic approaches emphasized cooperation with Portugal and Morocco. Storage capacities were seen as a relevant factor in searching for partners. One German expert said that his country has no preferred CSP cooperation partner.

When asked about the (geo)political drivers and barriers for CSP cooperation mechanisms, the answers were very similar to the ones on renewable cooperation mechanisms: reducing energy dependence, diversification of sources, comparative advantages like insolation levels, economic/industrial considerations and providing stability to the EU electricity system. Most interviewees stated their CSP expertise was limited, but also mentioned that it is difficult to assess a technology in isolation. Nevertheless, storage capabilities and flexibility were considered valuable strategic assets by all the interviewees (but not all of them mentioned it immediately, but rather after being questioned on storage). Technological innovation, technology diversification, industrial development (having a consolidated industrial base) and the renewables-water nexus were also mentioned as CSP strategic drivers. Issues like CSP's role in grid communities (storage, interconnections, integration) or projecting CSP cooperation within the Energy Union and abroad as a soft power tool were also vaguely evoked.

Regarding the role the European Commission has played in fostering CSP cooperation mechanisms and which role it should play in the future, few interviewees were familiar enough with CSP or cooperation mechanisms to answer. However, most interviewees provided information regarding what the Commission should do. The ideas voiced include: resorting to the EU budget and regulation: regional funds, state regulation, investment in CSP technology, EU budget, strengthening enforcement capacity, pilot projects and break country divides, research and innovation. A German expert highlighted the need to put more "brain", and not only financing and regulations, meaning having a more comprehensive strategic view on CSP's potential and opportunities.

On the whole, the elite interviews confirmed the hypothesis that, while renewables have hesitantly entered the European geopolitical landscape (notwithstanding the deficits in understanding their geopolitical consequences), CSP and cooperation mechanisms have not. Experts were aware of the increasing importance of renewables in geopolitics, but few were familiar with the specifics of EU's renewable cooperation and exchange mechanisms and CSP. However, experts confirmed Europeanisation as the way forward, appreciated the role of the EU and demanded more initiatives from the Commission. They also showed interest on the issue and recognized that the immediate urgencies of fossil geopolitics overshadowed the long-term strategic implications of renewables and, especially, CSP. But contrary to other renewable technologies, most analysts are still considering CSP an “immature” and “niche” technology pre-destined to “fringe” geopolitics.

Furthermore, most interviewees also tended to consider cooperation mechanisms niche institutions. Diplomats tended to highlight the economic dimension of renewable technologies’ promotion, appreciating the soft power of renewables and being happy to have one more renewable technology like CSP in their portfolio. An interviewee pointed to German renewable cooperation in North Africa, like the KfW support to the Noor CSP project in Morocco. Interviews also revealed the tendency to deal with CSP exports like oil and gas flows, a symptom that CSP shares the “fossilization” (Raman, 2013) syndrome that seems to afflict the general European strategic approach towards renewables.

In sum, renewable geopolitics was generally perceived as something to be dealt with externally (with external policies like securing resources and corridors) rather than internally (with internal policies deploying European renewable resources and electricity corridors). For Spanish analysts, the combination of geographic and technology specialization makes countries like Spain and Italy being more interested in CSP than France, for instance. Nevertheless, piecemeal approaches and the lack of a holistic view make it difficult to allocate complementary roles to different technologies, especially for those considered niche technologies like CSP. CSP cooperation as a “soft power” tool was only vaguely evoked. Box 1 summarises the results of the interviews.

Box 1: Summary of elite interviews with experts and policymakers
(11 interviews: 3 German, 4 Italian, 4 Spanish)

The interview show that CSP is largely absent

- No strategic vision regarding the geopolitics of renewables cooperation
- CSP does not even appear in energy security strategies
- Focus on gas, pipelines and hub competition (even among Member States)
- renewable mercantilism: reducing renewables imports and increasing exports, as well as promoting national industries/ companies
- renewables have entered the EU geopolitical landscape, but no strategic role assigned to CSP
- General lack of knowledge of renewables cooperation mechanisms and CSP

On the positive side:

- Europeanisation is perceived as key to promote renewables cooperation
- Interest in the issue, recognizing that fossil geopolitics overshadows renewables, especially CSP

3 Energy security

3.1 The investigated case: CSP for Spain and CSP in Spain for export northwards

In MUSTEC, we investigate how CSP can be deployed in Europe. We assess CSP deployment policy and strategies both for domestic use in the southern European countries that have suitable areas for CSP, and for use in other European countries through cooperation deals with southern European exporters. In this section, we evaluate the energy security impacts of new CSP projects in a fully or almost fully renewable electricity future, broadly following the scenarios of Schöniger et al. (2020). In these scenarios, CSP provides 2-5% of the electricity, mainly or exclusively as balancing power to stabilise the system and compensate for fluctuations of wind power and solar PV. In these scenarios, some 25-80 GW of CSP is installed in Europe; about half of this capacity is located in Spain and used both domestically and exported to other countries using the cooperation mechanisms.

The investigated CSP projects are, as in the integrated system scenarios of MUSTEC, large-storage (11 hours) stations of 200 MW (Schöniger and Resch 2019, Schöniger et al. 2020). This is quite different than existing stations, which are both much smaller (operational stations are on average 55 MW) and have smaller storage (on average 3.4 hours); it is, however, the size of the trough stations used in the Noor Energy 1 CSP complex, currently under construction in Dubai (csp.guru 2020). Whereas this will not allow each station to provide continuous baseload power – which is also not needed in a renewables-based system (Schill 2014) – such a storage size will allow a national fleet of CSP stations to provide fully dispatchable power to balance fluctuations of PV and wind power generation and to help cover night-time electricity demand even if gas power is completely phased out (Pfenninger et al. 2014a, Schöniger and Resch 2019).

As in most, or all, energy system scenarios, the modelled futures in MUSTEC are reliable in the sense that they have sufficient generation capacity available to satisfy demand in each hour of the year. Hence, these systems are secure under all expected and knowable conditions. Detailed numerical analysis of the energy security of such scenarios is thus not useful: it has already been done in the model runs of MUSTEC (Schöniger and Resch 2019, Schöniger et al. 2020). Instead, we here perform a qualitative assessment of the energy security in future fully or almost fully renewable power systems in Europe, focusing on how the energy security is affected by the addition of CSP as an additional dispatchable renewable technology, if expected or unknowable threats materialise.

3.2 Assessing energy security

3.2.1 What is energy security and what is it not?

In this report, we define energy security as the uninterrupted supply of energy to customers. This definition is more narrow than most definitions in the literature, but is nevertheless the only way to define the term in a way that both excludes concepts included in other energy policy aims (e.g. affordability, sustainability) and that makes contextualised analysis possible. Terms like "sufficient" energy supply, often included in definitions, are irrelevant in the electricity context, but are implicitly included in our definition: if the power supply is insufficient, the system is immediately interrupted, as it must be perfectly balanced at every instant.

Energy security is one of the most used, and hence also misused, terms in the energy policy debate. It has been called everything from "slippery" (Chester 2010) to "elusive" (Kruyt et al. 2009), "blurred" (Löschel et al. 2010) or "diffuse" (Sovacool and Brown 2010). Especially in the years around 2010, a rapidly growing literature spent considerable efforts to define energy security, without much success. Even after years of scholarly debate, definitions remained extraordinarily disparate, and if anything, the academic literature was further away from a common understanding of the concept after this set of papers was published than before it. It is striking that this stream of publications has all but stopped: evidently, leading scholars appears to have concluded (and instructed their PhD students) that energy security is rather an empty signifier than a precise concept. The words of Joskow (2009): "if you cannot think of a reasoned rationale for some policy based on standard economic reasoning then argue that the policy is necessary to promote '*energy security*'". Nevertheless, this stream of articles was useful because it highlighted the necessity of being precise with the boundaries – especially in excluding – of a concept when analysing it. This highly academic discussion was more than an ivory tower exercise, as the very disparate definitions lead to entirely different assessments of energy security.

And definitions indeed vary widely. For example, Yergin (2006) finds that energy security is "simply the availability of sufficient supplies at affordable prices", whereas the International Energy Agency adds that the energy must not only be available at sufficient amounts, it must also be delivered without interruption to the customers (IEA 2019). Others seek to explicitly include both different types of threats to energy and the system's ability to respond to disturbances; for example, Winzer (2012) after a detailed review concludes that "the common concept behind all energy security definitions is the absence of, protection from or adaptability to threats that are caused by or have an impact on the energy supply chain". Yet others view energy security to be a vastly multi-faced, multi-dimensional concept, consisting of 15 (Azzuni and Breyer 2018) or 20 "dimensions" (Sovacool 2011) to be assessed by up to 372 different parameters, ranging from the "use of the energy weapon" to "IT skills". Naturally, the result of an analysis of direct threats (e.g. natural disaster, terrorism) to supply continuity in a country (as in Lilliestam (2014)) may be very different than an analysis of direct threats plus sulphur intensity of electricity generation, R&D spending and retail prices of gasoline (as in Sovacool (2011)).

Despite the “emptiness” or “slipperiness” of the concept, energy security is of course a real thing, something that exists – if nothing else because *we*, be it policy-makers, scientists, or “regular citizens”, use it to describe something and manage to convey meaning to our counterparts: the colloquial use of energy security evidently has meaning. Although there is no unambiguously correct definition of what energy security is, when we experience energy insecurity, we can immediately and unambiguously identify it. A blackout or a gasoline shortage, for example, without doubt falls in this category, especially if such events are frequent or long-lasting. Most definitions in the literature reflect precisely this colloquial use and include, in one way or another, uninterrupted, reliable supply of energy to customers (Sovacool and Brown 2010).

Whether the other “dimensions” of energy security must be included in analysis depends on the scope of that analysis. Cherp and Jewell (2014) suggest that the very question about “dimensions” is not useful, and instead discuss why anyone cares about energy security in the first place: in effect, they argue, energy security is about ensuring the reliable functioning of vital systems. Energy insecurity is dangerous, because it threatens the effective functioning of the government, of food and health systems, the military, or the financial system. For these functions, the price of energy is irrelevant, at least in wealthy regions like Europe: there is no price for oil, no cost of electricity that is so high that a state is unwilling to pay it if state collapse is the consequence of not paying. If energy security is about the reliable functioning of vital systems, then it is practically a physical question of reliable supply to consumers, but not about price.

This narrow view of energy security as the physical reliability is further supported by conceptual analysis of overall energy policy aims. On the one hand, Yergin and the IEA correctly note that prices matter: if energy is in principle available but customers cannot afford it, then they experience energy insecurity, because they *de facto* cannot access it. On the other hand, if security means “uninterrupted and affordable supply”, then analysis of broader energy strategies is difficult, because the analytical scope becomes blurred. For example, the aim of the European Energy Union, the central process of the transformation of the European energy systems, is to achieve “secure, sustainable, competitive and affordable energy” (EC 2015). If, then, “secure” means “affordable and available” or “affordable and non-interrupted” energy (IEA), then some concepts appear twice, whereas the term “security” can be safely removed and replaced by “continuous/non-interrupted supply”. At least in the context of energy policy analysis, energy security refers to the stability of supply, to ensuring continuous supply to consumers under all foreseeable circumstances.

Hence, we here limit our view of energy security to the issues relevant for the reliable, uninterrupted physical supply of energy. This then includes physical issues often discussed, such as energy being “available and sufficient”; especially in electricity systems, in which supply and demand must be exactly balanced at every instant, reliable supply must be available and sufficient, or the system will fail. This definition also focuses on short-term reliability in already existing systems (as described in energy scenarios), and hence excludes aspects which may affect reliability in the long term, if left unchecked, such as underinvestment and climate change-related events (e.g. heatwaves disabling power generation, reducing transmission capacity).

3.2.2 Resilience and threat-specific assessment

To understand whether a power system or an electricity scenario is secure or not, it is important to focus the analysis on specific threats to energy security. The literature is awash with generic frameworks, often the result of the definition exercises discussed above, but the threat to energy security is not generic: it is always specific, and although we cannot know exactly what will happen in the future we can know how different types of threats play out.

The key to understanding whether a threat is significant is not its likelihood but the expected effect, should the threat materialise. Importantly, this must include the affected system's expected response to that particular threat. The resilience of a system is thus more relevant than its exposure to threats: things happen, but if the system is not affected, the vulnerability is low.

Modern power systems are highly resilient against shocks of various kinds and are very reliable: most customers in Europe experience on average 100 minutes of unplanned power outages per year (CEER 2018). This high reliability is possible because power systems are resilient against threats that happen frequently. Because continuous stable operation is the paramount objective of power system operators, systems will have protection measures against the most common threats – they will be designed to withstand precisely these common events. For example, because power stations and power lines sometimes fail, and as there is no way to eliminate that threat, power systems are designed to withstand the sudden failure of any one component. This principle is known as the n-1 principle, and is the basic security paradigm of power systems around the world, including in Europe.

In real power systems, practically all blackouts happen because of technical failures or natural events, especially lightning strike or storms. In many cases, blackouts happen because the n-1 principle was violated and a single event, even a single planned event, leads to a cascade of errors and, eventually, a blackout. A prominent example of this is the 2006 Western European blackout, which caused by the manual, planned disconnection of one line after the operator incorrectly believed that the power could be safely rerouted. This mistake led to overloads in parallel lines, which defaulted and eventually blacked out all of Europe, from Hamburg to Casablanca (UCTE 2007, van der Vleuten and Lagendijk 2010). Such events, while highly relevant in power system operations, are irrelevant in scenario analysis: such operational mistakes are impossible to meaningfully analyse for the distant future. Importantly for our analysis, operational mistakes may happen with the same effect and similar likelihood in any power future, with or without CSP.

Nevertheless, history shows that it is critically important to think about the nature of the threat, and not only the nature of the technical assets. Many of the most severe blackouts are caused by multiple failures – including multiple failures due to a single cause. A prominent example of this is the 2003 Italian blackout, in which all of Italy lost power. This event was triggered by a storm in the alps, which caused tree flashover and the sudden disconnection of a line carrying power from Switzerland to Italy. The system withstood the first line failure, but only by temporarily overloading a parallel line; this line sagged – very likely due to thermal expansion caused by the overload – causing a second tree flashover in the same storm. As this second line tripped, northern Italy experienced underfrequency and disconnection of units, and the fault rapidly cascaded all the way to Sicily (UCTE 2004).

In cases such as the Italian storm in 2003, the system may be n-1 secure in the technical sense – it can withstand the failure of any one unit – but not in the systemic sense, as it did not withstand all effects from a single event (Lilliestam 2013). This is a common cause for catastrophic failure, and was also the case for example in Fukushima: *one* earthquake tripped the power supply to the reactors *and* set off a tsunami that flooded the emergency power supply. The Fukushima reactors were technically n-1 secure, but not systemically: a single threat was sufficient to destroy the whole facility.

Hence, it is necessary to think about specific threats and how they could play out in the system: what assets, which systems could it affect, and what do we know about the system's resilience to that particular threat?

Of course, it is unfeasible to foresee all possible events, or the details of a specific event, especially several years or decades in advance. Detailed quantitative analysis of such events is hardly useful, and we do not attempt it here. Nevertheless, the effect of any reliability-relevant event in the power system will be either a loss of generation or demand, or a loss of transmission between two points; the system effect – too little supply or too little demand (or both, but in different places, if a line trips) – is the same regardless of the reason: a terrorist attack, an earthquake and a short-circuit may all suddenly disconnect a line, a generator or a consumer entirely. The specific cause can however have an impact on the probability of an event happening: whereas natural and technical events happen with some likelihood, human-caused threats happen through malice and are unlikely to happen if the intended effects – a blackout, fear, or economic loss – are small (Lilliestam and Ellenbeck 2011, Lilliestam 2014).

A future power system relying strongly on fluctuating renewables must be designed to withstand the most severe threat to stability: the intermittency of wind and PV power, and the rapid and sustained loss of very large generation capacities. These threats include foreseeable events (e.g. sunset, weather fronts passing the country/continent) which happen regularly or at least frequently and require, renewables-based systems to have large flexible capacities to handle very large fluctuations (Schlachtberger et al. 2017, Child et al. 2019). These flexible capacities will be useful also against unforeseeable events, such as terrorist attacks or natural disasters (Lilliestam 2013). A renewables-based system will thus be more resilient than a fossil fuel-based one, simply because it must in order to be viable (Lovins and Lovins 1982).

3.2.3 Energy security as the relative reliability of scenarios: assessment heuristic and investigated threats

If energy security in the power system means reliable supply of power to customers, one must ask how reliable is reliable enough. A strict interpretation of "non-interrupted" is unfeasible: there will always be interruptions, caused by failing technology, natural events, or mistakes, so 100% reliability is not a useful benchmark. From an economic perspective, the optimal – or efficient – level of reliability is reached when the marginal cost of investments to increase reliability equal the marginal cost of interruptions (de Nooij et al. 2009); in this perspective, an energy system can be too reliable. In Europe, the very reliable electricity supply is reliable enough, (or possibly overly reliable), as the present reliability is not a threat to vital systems: governments do not fall, states do not fail, and companies are not forced out of business due to unstable power supply.

Whereas it is not possible to objectively say *ex ante* what level of reliability is reliable enough, it is possible to analyse differences between scenarios: we can robustly say whether a scenario is more or less reliable than another, whether the vulnerabilities are larger or smaller. We adopt this approach here: we do not assess the reliability of the electricity scenarios in absolute terms (which is done in the MUSTEC power system modelling (Schöniger and Resch 2019, Schöniger et al. 2020), but only in relative terms: how much more or less reliable is one scenario compared to another?

In this report, we assess the effects of adding CSP to renewable power scenarios in Europe. An important consequence of measuring relative reliability is that we do not have to assess all threats to the power supply, but *only those that are different*: all threats that are identical in scenario 1 and 2 cancel out when comparing them. This means that we only assess the aspects of the power system that are directly affected by the addition of CSP, while excluding all other potential threats to the European power system.

As CSP is a supply-side option, connected to the transmission grid, we do not consider effects on lower voltage levels, including the distribution grid. Further, we do not investigate threats affecting the general transmission system, for example storms and earthquakes, as such threats are not directly affected by the presence of CSP. In particular, we do not investigate the possibly most severe threats to electricity systems in Europe: targeted cyber attacks against the transmission system control system (Onyeji et al. 2014, Liang et al. 2017). Because CSP stations do not offer any specific new attack vector, and as serious cyber attacks would rather affect the transmission system than single power stations, the – very serious and very real – threat of cyber attacks is identical in all scenarios. Finally, the threat of a power station failing is identical to the station failure threat in other scenarios: any station may fail, which is why all generators fall under the n-1 principle. The same applies for the connector line between the station and the main grid: that line may fail, but so may connector lines from all types of power generators, with the same effect (none, if the system is n-1 secure) and the same probability.

Only a small set of energy security-relevant features are CSP-specific and different than in a renewable power system without CSP. Prominently, this affects the **intermittency** risk – the threat that weather conditions do not allow for sufficient power generation to satisfy demand. Because CSP can only be efficiently deployed in dry regions with high direct normal solar irradiation and such conditions are not present in large parts Europe, and also not everywhere in southern Europe, CSP fleets may be concentrated in some geographically limited areas. This will have two reliability-relevant consequences. First, if the entire CSP fleet is located in a limited region – if the **generation is geographically concentrated** – it is likely to experience the same or at least highly correlated weather conditions, so that larger capacities are disabled during adverse weather conditions. In addition, near-by stations are more likely to be affected by one and the same event, especially large-scale natural events like earthquakes or storms.

Second, because the large cities tend to not be in the sunniest, driest regions, large amounts of CSP electricity cannot be absorbed locally but must be transmitted over long distances – and these lines constitute **chokepoints** that may fail or be attacked. This risk is the same as for, for example, offshore wind, but it may be different than for PV and wind generation (which can be and is often located in or near cities). The transmission chokepoint failure threat may be particularly important for CSP cooperation, in which CSP is generated in the south and consumed in central or northern Europe. If CSP is transmitted via dedicated HVDC lines, such as suggested by DESERTEC and the DLR (Trieb 2006, Desertec 2009, Trieb et al. 2015, Trieb et al. 2016), each line constitutes a chokepoint: as such lines are generally very large, losing one could cause reliability problems on the receiving end. Even if the export happens via the main HVAC transmission grid, there may still be chokepoints; for CSP, this especially applies to the lines crossing the Pyreneans, where large capacities may be focused in single lines or in multiple lines nearby each other and hence susceptible the same natural events.

Finally, disrupted value chains may pose a **geopolitical threat** to European energy security. This refers both to disrupted flow of imported components and disruptions to service of existing stations; both may force running stations offline, permanently or for extended periods of time. Because our analysis is limited to domestic and intra-European electricity trade, the classical, geopolitical energy security aspect of the “energy weapon” is irrelevant, as there is no import of electricity to the European Union, but only trade within the EU. The possibility of trade interruptions between EU countries, or the collapse of the EU and subsequent hostility between previous Member States, is not considered here.

3.3 Energy security impacts of CSP

The main energy security effect of CSP is positive, both when CSP is traded in cooperation between countries and when it is used domestically: CSP offers precisely the flexible generation renewable power systems need, by being able to generate solar electricity also after sundown or during adverse weather conditions (with the MUSTEC station configuration, up to 11 hours at full load). Even with the relatively small capacities installed – the MUSTEC scenarios foresee 20-80 GW, Europe-wide – CSP offers a vital function to the system –multi-hour balancing, such as night-time solar power, that no other technology can provide at the same low cost as CSP. Without CSP, the system would thus be less reliable, or equally reliable but more expensive.

The generation concentration risk is similar to wind power options, but is larger than the concentration risk for typical PV systems; supply disruptions from this threat are however unlikely. The chokepoint risk exists for CSP, especially in cooperation cases, as they rely on long-distance transmission, at a similar level as for offshore wind, which however – other than CSP – *necessarily* depends on long-distance transmission lines. The geopolitical threat to CSP is miniscule and comparable to that of wind power, and likely even smaller than for solar PV.

Compared to alternative supply options, CSP is more secure and adding it increases the reliability of the power system. The intermittency risk is the by far dominant threat to reliability in renewable scenarios compared to other futures, and this is much less important for CSP than other technologies. Indeed, the main rationale for adding CSP in Europe is to handle this threat. Our main finding applies to CSP additions both for domestic use and for export: from an energy security perspective, adding CSP is a robust choice.

3.3.1 A new security paradigm

All scenarios generated in MUSTEC are, just as all other renewable electricity scenarios, *secure*: these scenarios show different renewable power futures in which the supply is always sufficient to cover demand. This means that, assuming that the technical supply system has no faults and always works, all generated scenarios are perfectly reliable (Schöniger et al. 2020).

The main difference in fully renewable power scenarios and today’s system, or scenarios with fossil fuel generation, is the nature of how reliability is ensured. In today’s system, the fluctuating demand is met by regulating dispatchable fossil fuel power stations, such as gas power, up and down. The current power supply is fully controllable and is made to always exactly match demand. In such systems, the concept of (inflexible) baseload generation makes sense to cover the minimum load, and flexible mid- and peak-load generators to cover the (fluctuating) rest of demand (Pfenninger et al. 2014b).

In a renewable electricity system, the demand still fluctuates as it does today, but also the supply is fluctuating, depending on the momentary solar and wind conditions. Hence, reliability becomes a stochastic measure: a scenario will have sufficient capacity to cover demand even during periods of high demand and low solar and wind power generation, *given what we know about weather patterns* from the last 50 years or so. The system is designed for this worst case, and backup options such as long-term storage are designed to suffice during such periods. The system stability, and hence the reliable supply of vital societal functions, depends on weather patterns remaining as they have been, and especially of combined low wind and low sun periods not being much longer or deeper than anticipated. As both the demand and the supply are fluctuating, traditional generation profiles (base-, mid- and peak-load generation) are not relevant: there is flexible and inflexible supply (Sovacool 2009, Schill 2014, Ueckert and Kempener 2015).

In this new reliability paradigm, CSP can play a key role as one of the few supply-side flexibility options that can be scaled up to cover large shares of the supply. By supplying flexible power, CSP is thus both a reliability-enhancing technology and an enabling technology for fluctuating renewables: a renewable power system will only materialise if it has measures to ensure stable operations, and CSP can be one of these measures. In addition, the dispatchability of CSP may increase the legitimacy of renewable power systems: it may be politically more attractive to “be in control” of critical infrastructure and the reliability of electricity supply than to be dependent on the weather.

3.3.2 Intermittency threat

The rationale for adding CSP to the European electricity system is one of reliability. A kilowatt-hour of CSP is more expensive than one of PV or wind, but it is also of a different quality: the CSP kilowatt-hour is dispatchable and can be generated when it is needed, whereas the PV or wind kilowatt-hour is offered whenever the resource for producing it is available, regardless of whether it is needed at that time. All scenarios generated in MUSTEC are reliable in the sense that they have sufficient generation available to cover demand during all hours of the year; as these scenarios were developed using data from several weather years, they are also reliable during periods of extended low solar irradiation as observed in the past. In this, CSP is one of the technologies used to balance the system and to buffer supply fluctuations, especially on the time-scale hours-days.

In a future system based on fluctuating supply, there is no need for baseload generation; as such power is highly inflexible, it would likely increase system cost (e.g. due to increased curtailment, wear-and-tear from ramping baseload generators) and could even be a threat to system reliability. Instead, flexible generation, capable to quickly ramp up or down depending on the actual or predicted generation of fluctuating sources is necessary (Schill 2014, Eser et al. 2016, de Mars et al. 2020). This is precisely the function CSP can supply: depending on the storage size and the solar multiple (ratio solar field – turbine), a fleet of CSP stations can be designed to provide any degree of dispatchability, from low load-factor electricity to entirely load-following power (Pfenninger et al. 2014a).

Most other flexibility options offer short-term services, but are either incapable of providing longer services, or doing so would be expensive. For example, demand-side response measures have a very high potential of several gigawatts, comparable to current spinning and primary reserve capacities, but it cannot be maintained for long times: disconnected industries and private or commercial appliances must be reconnected quickly, often within minutes (esp. industry) and generally within an hour (e.g. refrigerators); even space heating processes cannot remain disconnected indefinitely but must resume operation within a few hours. In consequence, demand-response measures may be very important for short-term balancing, but are hardly useful for multi-hour system functions (Aryandoust and Lilliestam 2017). Often, authors discuss a competition between the solar technologies, between CSP with thermal storage and PV with batteries; because especially battery technology is advancing very rapidly, a future with both low-cost PV and low-cost batteries is conceivable (Mehos et al. 2015, Feldman et al. 2016). However, even with very optimistic assumptions on battery technology development, CSP with thermal storage will likely remain the least-cost option for storage durations exceeding 8 hours, whereas it currently is the least-cost option for storage exceeding 2 hours (Schöniger and Resch 2019, Schöniger et al. in review)

CSP can thus provide a system function that other flexibility options cannot provide, or at lower cost than competing technologies; this reliability-enhancing effect will be present both in purely domestic CSP schemes and in a CSP cooperation future. If CSP is traded between countries in a cooperation scheme, it will necessarily come with expanded transmission and interconnection capacities, as the interconnection capacities from Spain to France, from southern to northern Italy (and on to France, Switzerland and Austria) or from Greece to its northern neighbours are currently too weak for large-scale CSP exports (ENTSO-E 2019). This expansion of interconnections can (and will) also be used to transport wind and solar PV power, and will effectively increase the degree of interconnection within and between countries: this will smooth the fluctuations of especially wind power and make the fleet output more predictable (Holttinene et al. 2011, Ueckert and Kempener 2015, Grams et al. 2017).

3.3.3 Geographical concentration threat

Concentrating solar power collects the heat of the sun and uses it to generate electricity. Therefore, it requires strong direct normal irradiation (DNI) to work efficiently. Such solar resources are found in areas with low humidity and especially on low latitudes (Romero and González-Aguilar 2014, Mir-Artigues et al. 2019). In Europe, such regions are found only in the southern-most parts, especially in the south-eastern half of the Iberian Peninsula, but also in the southern tips of Italy and Greece. Here, and only here, are both the DNI and the number of sunny days particularly high, increasing both the economic attractiveness of CSP and the predictability of the electricity output from a CSP fleet.

Nevertheless, also such sunny regions may experience extended times of low DNI. Many locations experience seasonal weather patterns, such as the monsoonal patterns in India or south-western US, prohibiting CSP from generating high load-factor, continuous solar power during these parts of the year (Pfenninger et al. 2014a). In Europe, the main seasonal weather pattern is the strong summer-winter change in solar irradiation: even in southern Europe, the winter sun is less than half as strong as the summer sun. With increasing latitude, the winter-summer variation increases: around the Northern Seas, for example, winter solar irradiation may be 5% or less compared to that in high summer (Czisch 2005, Czisch 2006).

This natural variation of solar irradiation has effects both on the solar power fleet and the way such fleets are planned. These effects can work both to increase and decrease the reliability of a CSP fleet compared to a PV fleet.

As CSP is only economically meaningful in southern Europe where the DNI is high, a European CSP fleet will avoid the very large seasonal fluctuations of PV generation in the north: whereas norther European PV generation will fluctuate very strongly over the year, a CSP fleet located in the south will fluctuate to a much smaller extent, given the smaller winter-summer fluctuation in irradiation in southern Europe. In this sense, CSP will have a positive impact on energy security in Europe, especially in cooperation schemes in which CSP is transmitted to central and northern Europe: CSP trade would effectively make the stronger winter sun of the south available also to northern countries, allowing them to replace the lost PV generation in winter or to balance the wind power fleet.

On the other hand, the European regions best suited for CSP are geographically rather small, spanning only up to a few hundred kilometres. Hence, the weather conditions in each of these CSP generation regions are likely to be strongly correlated: the weather and hence the solar availability in any given hour is likely to be similar in Sicily and neighbouring Calabria, or in Extremadura and nearby Andalusia. Because the entire national (Italian or Spanish) CSP fleet experience the same weather, the degree to which the CSP fleet is dispatchable is limited (Pfenninger et al. 2014a), both for domestic CSP and CSP cooperation schemes relying on generation from only one region. As CSP is used precisely because of its dispatchability, a failure to provide this system function may have large effects in the entire supplied system. However, as the scenarios generated in MUSTEC already take into account past weather patterns, this threat will only materialise if weather patterns change and phases with cloudy weather are longer in the future than they have been in the past.

3.3.4 Chokepoint failure threat

As described above, infrastructure failure is the by far most common source for blackouts in Europe. However, this threat will remain in all renewables-based systems, and be of comparable magnitude: every system will be n-1 secure, meaning that it will withstand the failure of any one component at any time. With growing shares of renewables, transmission will likely become more important, both to transport electricity from remote generation sites and, especially, to balance and smooth fluctuating feed-in (see section 3.3.2). Power system models suggest that that in systems relying mainly on such stochastic smoothing to balance wind and PV power fluctuations, the transmission needs are 2-4 times larger than the current system (Tröndle et al. 2020), but there are also studies suggesting that up to 12 times the current transmission system may be required (Rodríguez et al. 2014). Such vast transmission systems are on the one hand more exposed to failing units – simply because there are more assets that may fail – but are also likely to be more resilient and capable to absorb disturbances, as there are more assets to distribute the failed capacity onto.

Adding CSP to a power system will not *per se* affect any particular infrastructure threat: each CSP station will be connected to the grid and that connection line may fail. This is however the case for every on-grid power generator. Historically, CSP stations have been relatively small, with each station connecting 100 MW or less to the grid, so that each single unit is very unlikely to be relevant for system operation. In Europe, the n-1 criterion corresponds to 3000 MW in northern/central Europe and 1500 MW in other parts (ENTSO-E 2009, Lilliestam 2013). Even the currently largest projects consist of single units connected separately to the grid; the currently largest CSP complex in the world, the 700 MW Noor Energy 1 under construction in Dubai, has 4 separate units (3x200 MW, 1x100 MW; Lilliestam et al. (2020)). Modern wind farms and PV fields often of several hundred MW, meaning that in terms of generation chokepoints, CSP is unlikely to form an additional threat.

In CSP cooperation projects, however, the CSP trade may add further risks: for such trade to be viable, new transmission lines are needed (Trieb et al. 2015). Whereas new CSP stations, regardless of if their electricity is bound for export or not, will likely connect to the domestic HVAC grid, the export is only feasible with strong northward links (Zickfeld et al. 2012, Welisch et al. 2016, Schöniger et al. 2020). Especially in the case of Spain, this is likely to lead to the emergence of new transmission chokepoints: because the Pyrenees effectively separate Spain and France, a densely meshed grid in this region is unlikely – this mountain range is likely to remain a bottleneck also in the future, with few but large trunk lines crossing it. Especially if they are drawn in the same regions (e.g. parallel to the existing pass roads), multiple lines may be affected by the same threat: for example, one storm may affect several nearby links, which could violate the n-1 criterion and cause a blackout. This problem is likely going to be larger if the exports are done by HVDC lines directly connecting the generation area with the offtaker region, bypassing the general transmission grid of the exporting country (Trieb et al. 2015, Trieb et al. 2016): as HVDC lines tend to have higher capacity than HVAC lines, such an export scheme may further bundle transmission capacity and exacerbate the transmission chokepoints threat. Hence, in cooperation schemes, it is important to ensure that the bulk trade lines are far apart and that they are small enough to fall under the n-1 criterion (Lilliestam 2014).

3.3.5 Geopolitical threats

It is extremely unlikely that materialising geopolitical threats to CSP, or any other renewable power technology, will cause power system failures. In particular, this threat is very small because the time scale over which geopolitical threats would affect power system reliability in a European renewable power system is very long – much longer than any response to the particular problem will be.

Currently, PV module manufacturing takes place almost exclusively outside the European Union, and especially in China and Taiwan. In the event of a crisis, including geopolitical tension but also disrupted supply chains such as powerfully demonstrated during the initial Covid-19 months in 2020, Europe risks being cut off from deliveries of such products (Weko 2020). Arguably, the same could apply to CSP, if the components for a CSP expansion in Europe are imported. However, as there is a very long time lag between a disrupted supply chain for power station components and any effects on power generation in Europe – a PV module, for example, is designed for a technical life exceeding 20 years – it is extremely unlikely that such disruptions will affect European energy security. Such disturbances in component flow, if sustained over a long time, could affect the deployment speed for renewables, but it is very unlikely to ever be a threat to power system reliability.

More complex technologies, like wind power and CSP, rely not only on bulky and highly specialised components, but also on highly specialised engineers to service the stations and repair them if they break down (Huenteler et al. 2016, Gosens et al. 2020). This threat materialised during the travel bans of the Covid crisis in spring 2020, in which engineers were unable to travel to wind farms in need of service (Parnell 2020). However, only some 5% of wind farms are disconnected for major technical work each year, so that also in this case, the service interruption would need to be very long, several years, before it becomes a threat to power system reliability. For CSP, the effect would be similar: also CSP stations can generally run for several years with maintenance carried out by the station staff before they must be taken offline for major repairs.

In addition, the geopolitical threat to CSP depends on whether the expansion is done mainly with European technology and engineers, or if it is rather done with foreign technology and knowhow (see section 4.3.2). The key products that could threaten the continuous operation of a CSP station are heat transfer fluids (thermal oil or salts), which may need to be replenished several times during the life time of a CSP station (Vignarooban et al. 2015). All further components and systems may, of course, also break down, but as these are either low-tech (e.g. mirrors) or are not CSP-specific (e.g. turbines), they can very likely be replaced or repaired with European components and by European engineers, even if the station is assembled by foreign components. Hence, value chains are at risk of breaking, and this risk increases with the length of the chain, but this risk should not be exaggerated (Hache, 2018; Overland, 2019). The supply chain for critical material is highly technology-specific, and so is the academinc literature for it: no peer-reviewed paper has been found dealing with the geopolitical specificities of the CSP technology or raw materials value chain. Preliminary findings suggest that, if anything, the risk of material shortage for CSP is smaller than for other electricity technologies, like gas power (Gamarra et al., 2019). In sum, it is very unlikely that broken value chains will remain broken, with no alternative emerging for such a long time that that the failed supply of components or services is a real threat to the European power supply.

4 FOSTERING CSP AND COOPERATION MECHANISMS AS A RESPONSE TO THE COVID-19 CRISIS

4.1 Impacts of the Corona crisis

4.1.1 European Union

In early 2020, the SARS-CoV2 virus spread from China to Europe and started spreading especially in Italy, Spain and Austria, before it took hold in all European countries, making Europe the "epi-centre" of the Corona pandemic in spring 2020. Whereas at the time of writing the first wave of infections has subsided in all EU countries and the virological aspect of the Corona crisis are, at least for the moment, under control, the economic effects are just starting show.

Across Europe, quarantines of individuals, familes and sometime entire companies, societal lockdowns and social distancing measures were implemented. A key measure in almost all countries was to close shops and recommend or require people to work from home, a measure that was reinforced by closing schools and daycare, effectively forcing parents to stay home. In consequence, economic activity has been greatly reduced, especially in the service sector, and consumption has plummeted across Europe. For southern Europe, the effects of the lockdown and social distancing rules are particularly gave: with non-essential travel grounding to a near halt and therefore also tourism and other related services on which several Southern Member States economies rely heavily.

These effects have had a massive effect on European economies: the projected loss in GDP exceed the losses in the Financial and Euro crises around 2010. In most European countries, 2020 will likely hold the most severe recession ever recorded outside wartimes.

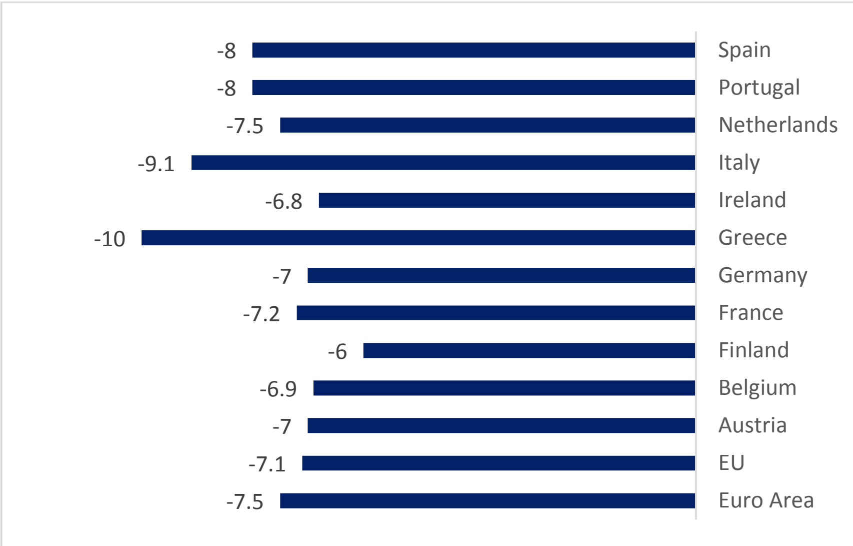

Figure 1: 2020 forecasted real GDP growth (%). Source: IMF (2020).

The estimates regarding the GDP losses, unemployment, deficit and debt figures of the Great Lockdown (IMF, 2020) are slowly emerging. Preliminary data from the IMF shows an expected percentage change in world output of -3% in 2020, a change that would amount to -7.5% in the Euro Area (IMF, 2020). In part because they were hardest hit by the virus and were on lockdown the longest, but also due to expected losses in the tourism sector, the souther Euroepan countries will likely experience the strongest recession effects (Figure 1).

Energy consumption has collapsed accordingly, especially fossil fuels, but electricity markets have also been severely affected by reduced industrial and business consumption. Oil prices have reached historical lows, to the point that West Texas Intermediate (the benchmark in the US) oil futures reached negative levels for the first time (-36$). Electricity prices have also reached negative prices for some hours and days in several European countries (Escribano and Lázaro, 2020).

4.1.2 Spain

One of the hardest-hit countries in spring 2020 was Spain. In response to this, the Spanish governmemt imposed very strict lock-down measures, unprecedented in Europe both regarding strictness and duration. This proved effective against the virus and, at the time of writing, the infection speed had decreased very strongly, allowing for a slow re-opening of the country. At the same time, the economic effects were particularly strong, and the Spanish national forecasts (Table 1) are more alarming than the IMF's forecast (Figure 1), expecting GDP reductions ranging from 6.6% to 13.6% depending on the duration of the lockdown, the impact of the health crisis on the solvency of firms and the speed of economic recovery (Banco de España, 2020). The BdE's worst case scenarios consider 12 weeks of confinement, which was similar to the actual duration of confinement in some regions, including Madrid. The Spanish government has just sent the European Commission his updated Stability Program for 2020-2021 to account for the impact of the corona-crisis with a -9.2% GDP growth rate forecast for 2020 and a recovery for 2021 with a 6.8% GDP growth that year (Reino de España, 2020), which will leave the 2021 Spanish GDP 3% below 2019 levels. Some analysts perceive this forecase as over-optimistic, given the recent GDP growth rate reported for the first quarter (-5.2%), allegedly pointing to a real GDP growth rate around -11.5% for 2020 (Sebastián, 2020).

Table 1: BdE growth scenarios for Spain. Source: Banco de España (2020)

	Average annual rates		Confinement duration (in weeks)	Other key assumptions
	2020	2021		
Supply-side approach				
Scenario 1	-6.6	—	8	Almost complete normalisation after confinement
Scenario 2	-8.7	—	8	Almost complete normalisation in Q4 after confinement
Scenario 3	-13.6	—	12	Incomplete normalisation at end-year (particularly in sectors linked to accommodation and food service acvtivities and leisure)
Simulations with the MTBE				
Scenario 1	-6.8	5.5	8	The measures prevent lasting job losses and company closures
Scenario 2	-9.5	6.1	8	A certain proportion of firms do not manage to prevent liquidity problems from becoming solvency ones
Scenario 3	-12.4	8.5	12	A certain proportion (bigger than in scenario 2) of firms do not manage to prevent liquidity problems from becoming solvency ones

SOURCE: Banco de España.

The social cost of the lockdown is also expected to be very high. The updated Stability Program for 2020-2021 forecast a 19% unemployment rate by the end of 2020 (Reino de España, 2020). Figure 2 shows how, in March 2020 alone, social security registrations decreased by almost 800,000 workers, with the accommodation and food services, construction and the retail sector being especially hit. The currently observed development in Spain is thus comparable to, and may eventually exceed, the worst years of the Great Recession.

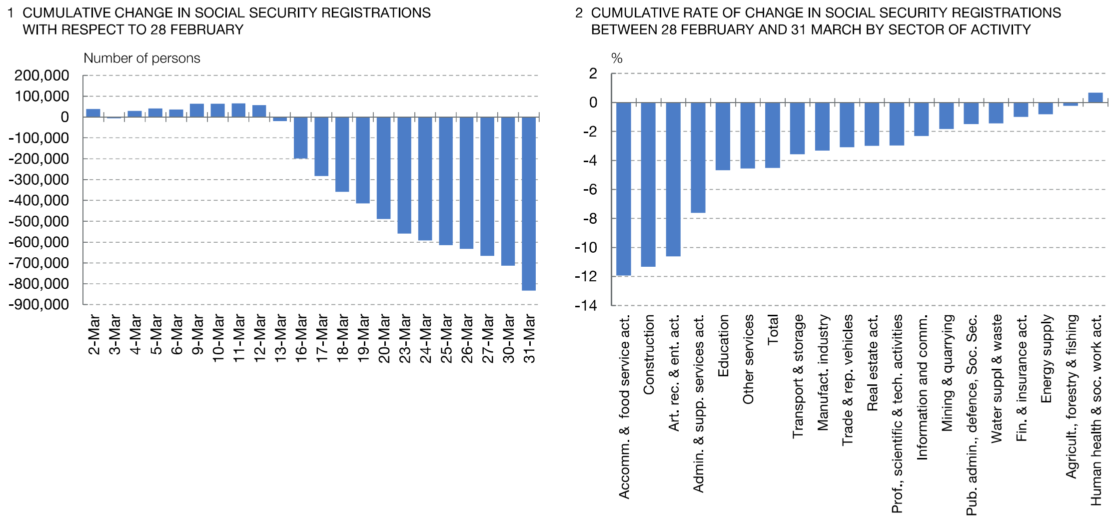

Figure 2: Change in social security registrations, total (panel 1) and by sector (panel 2). Source: INE-Instituto Nacional de Estadística

The Spanish energy sector has been severely affected. Energy demand has plummeted, especially fossil fuels, which have experienced the biggest year-on-year monthly average decrease in history: in March, the demand for gasoline had decreased by 79% for gasoline and the consumption of jet fuel collapsed by 93%. The crisis has also severely impacted the electricity sector, with the demand in April 2020 14% below the demand of the previous year; this effect was especially strong in industry, which saw a 15% low-than-normal power demand[1].

4.2 The responses: the Green Deal and Corona recovery plans

The current European energy and climate policy debate revolves around whether the EU's and Member States' response to the crisis might help align economic recovery plans with energy transition and climate policy; or whether said response may result in stagnation and even reversal of the unfolding European low-carbon transition pathways towards carbon neutrality by 2050 (Escribano and Lázaro, 2020). It is extremely unlikely that the economic policy response to COVID-19 will be climate-neutral, and we can already see that not climate-compatible sectors, such as airlines, are receiving substantial state support in most European countries. History tells that in times of economic crisis, it is not easy to direct investments so as to both solve the economic

[1] Fuel data from CLH; March electricity data from REE, April data obtained from consultations with electricity companies.

problem and redirect activity to also take steps towards greening the recovering economy. In the aftermath of the global financial crisis of 2008, for example, only 15% of global economic stimuli was green, despite repeated calls for a green recovery (Barbier, 2010; Bowen et al., 2009) and some positive experiences (Mundaca and Damen, 2015; World Bank, 2010).

Nevertheless, the context today, in 2020, is different from 2008. There is more scientific evidence on climate change and its effects, the Paris Agreement provides a consistent climate governance framework, and climate legislation has increased twenty-fold since the 1990s (Averchenkova et al., 2018). The cost of renewable technologies has decreased sharply in the last decade, with renewables being the cheapest way of producing electricity in most locations worldwide (IRENA, 2019). The drop in the price of fossil fuels offers the opportunity to phase out subsidies and increase taxes while limiting the impacts on vulnerable consumers (Benes et al., 2015). Citizens around the world are increasingly concerned about climate change as a threat and demand action from their governments nationally.

The calls for a green and just recovery plan for COVID-19 are increasingly loud. Demands for a green economic recovery after the initial response to the pandemic have been voiced by the UN Secretary General, Antonio Guterres (UNSG, 2020), the Executive Director of the International Energy Agency (IEA), Fatih Birol (2020), the European Parliament (2020), asset managers (Moritz, 2020; Thallinger and Robins, 2020), academia (Hepburn et al. 2020; Rosenbloom and Markard, 2020) and civil society (Transport and Environment, 2020).

In Europe, the adoption of the European Green Deal and the European Climate Law, Member States' framework Climate Change and Energy Transition Laws (existing or upcoming), and Integrated National Energy and Climate Change Plans (NECPs) and Long-Term Strategies (LTS) can provide the regulatory certainty the private sector needs for embracing the low carbon transition (Campiglio, 2014). In response to the Corona crisis, the Commission has presented plans for a European Recovery Plan, a stimulus package of 750 billion Euro to be raised and spent 2021-2024 (EC 2020); whether and to what extent this plan has a "green" component is unclear at the time of writing in June 2020, as is the extent to which this Recovery Plan is complementary to or overlapping with the already planned 1 trillion Euro Green Deal. The EU has produced a framework for aligning financial and climate goals through the Action Plan on Sustainable Finance and the recently published taxonomy, among others. Never before has the EU had this amount of shovel-ready climate *acquis*, reducing the policy space to reverse the trend of increasingly ambitious energy and climate policies and regulations that have been recently adopted.

A significant number of Members of the European Parliament (MEPs) and companies have supported Canfin's (2020) Alliance for a Green Recovery. Compared with the 2008 crisis, the growth of the green economy sector has modified political economy balances towards a more favourable equilibrium, further constraining governments' capacity to reverse course in their decarbonisation pathways (Meckling et al., 2017). This trend can be reinforced by the erosion of oil and gas incumbents' political influence due to the collapse of hydrocarbon prices and companies' shares (Escribano, 2020a). Internationally, European citizens consider climate change as one of the top foreign policy priorities in countries like France, Germany, Sweden and Spain (Real Instituto Elcano, 2018, 2020).

Also in the business community, the support for a green recovery focus is strong. For example, the Spanish Green Growth Group (GECV, 2020), representing over half of the Spanish benchmark stock market index IBEX-35, put forward suggestions for how such a policy could be designed (summary in Box 2).

Box 2: Spanish Green Growth Group Alliance for Green Recovery

Initiative	**Comments**
Alliance for a Green Recovery Acciona, BBVA, Iberdrola, Santander…	Banks coming in later
Spanish Green Growth Group 50 firms >50% of sales >40% of the companies in the benchmark Stock market reference index (IBEX35) 5% employment/active population	1. Stimulus packages should be aligned with climate and sustainability goals 2. Support the European Green Deal as a roadmap for recovery via decarbonisation and digitalisation 3. Spain should plan its recovery with the INECP (that should be accelerated) and the CC-ETL (that should be adopted) as guidance.

Source: GECV (2020)

Similarly, political parties across Europe, except most extreme right parties, generally support a green recovery deal. For example, Germany ear-marked 50 of the 130 billion Euros of its national stimulus package for green investment, including support for electric car sales and digitalisation, with broad support from most parties in parliament (DW 2020). Also in Spain, the political support for a green recovery is reasonably aligned (for Spanish political standards), except in thepopulist-nationalist party VOX, tend to be reasonably aligned (for Spanish political standards). Box 3 summarises Spanish political parties' attitudes towards Green Recovery, showing some space for political consensus, albeit with added hurdles. Like the government coalition parties, conservatives and center-right parties (Partido Popular and Ciudadanos) both signed the Alliance for Green Recovery, even if some infra-specification in their respective proposals and several nuances remain. Only VOX openly rejects the European Green Deal and proposes to devote EU's €1tn for the 'climate emergency' to the health and economic crises and to abandon the European Green Deal.

Box 3: Spanish political parties' attitudes towards Green Recovery:
Continued space for political consensus, albeit with added hurdles

PSOE-UP (government) **Socialist and far-left** **Government & grassroots**	**Partido Popular (PP)-** **conservative** **Market-based response**	**Ciudadanos - Centre right** **(E) Market-based response**	**Vox – far right** **Non-issue. No response**
Draft CC-ETL	Draft-CC-ETL	Acceptance of CC-ETL in electoral programme. No draft	On CC: Anthropogenic climate change unproven. Climate policies are totalitarian Obscure economic interests behind climate policies. NO CC-ETL proposal
Hectic (technical) agenda INECP, H2, Storage, offshore, NAP (with external effects- Open to consider limits of adaptation & ecological security)	Recently announced they would support: Spanish Strategy for circular economy an EU green Agenda for Smart Ec. with the **EU Green Deal as a roadmap. 'Ratified Alliance for a Green Recovery'. Will provide clear position in the coming weeks'**	**Signed Alliance for a Green Recovery**	Potential climate/low transition action if: energy independence at stake/national security can be enhanced. **Danger of securitisation**
TR/VP signed Alliance for a Green Recovery Relatively low (green) profile until very recently in the media. TR/VP de-escalation conundrum Requesting conditionality in aid	Sectors for green recovery and finance: Transport, renewables, renovations, R&D, biodiversity But...declarations have been mixed. Unclear on conditionality.		Published 10 measures for 'protecting Spain'. 5. 'Given the EU paralysis, EU's €1tn for the 'climate emergency' should be devoted to the health and economic crises. i.e. **abandon the European Green Deal**

Source: own elaboration

Despite the overall positive environment for a green exit to COVID-19, the post-corona recovery devil will be in the 'colour' of the stimulus packages and in the conditionality details. Even if initial reticence by some EU members seems to have been assuaged (EC, 2020) some voices within the EU and across the business community have demanded abandoning the European Green Deal (Euractive, 2020), relaxing or delaying the implementation of environmental consultations and regulations (Business Europe, 2020) and eliminating the price signals provided by environmental taxation while stimulating demand without any climate 'strings' attached (Alianza por la Competitividad de la Industria Española, 2020).

At the time of writing 4% of the global recovery packages (that amount to US $7.3 trillion) have been branded green, a further 4% brown and 92% 'colourless', i.e. geared towards maintain the *status quo*. This does not include the EU's 1 trillion Euro Green Deal, which was planned before the Covid crisis. Based on the results of a recent analysis of 700 stimulus policies deployed since the Global Financial Crisis of 2008 and on a survey of financial experts from ministries and central banks conclude that investments in renewables, storage and grid modernisation are superior in economic terms to traditional fiscal stimulus. This is so as short-term job creation is high and long-term savings on fuel provide higher multiplier effects. As for green bailouts for high emitting sectors such as airline companies and the oil and gas sector, academics and experts recommend that these should be conditional on companies presenting their pathways to Net Zero, 5-10 year intermediate targets and the conversion of bailout funding in equity at current prices in case of non-compliance with the decarbonisation roadmap Hepburn *et al.* (2020).

Given the current context, we think it is likely that the political "2020 green recovery battle", at least in Europe, will be fought not on the margins of stimulus packages, as was the case in the aftermath of the 2008 financial crisis, but that green-ness will be at the core of recovery programs. The clash between a green and a brown- with-shades-of-green recovery will continue to evolve as stimulus packages are designed and sanctioned by governments. The future of the CSP industry could hence be partially determined by how the debate and actions for the COVID-19 exit strategy unfold.

4.3 Should CSP and CSP cooperation be part of the recovery progammes?

4.3.1 Political barriers and leveraging (geo)political benefits

Currently, CSP and renewable electricity cooperation are not on the political agenda in Europe: only Spain considers a CSP expansion, but has no policy for this beyond a 5 GW target for 2030, and no country plans to import substantial amounts of renewables in the next 10 years (Lilliestam et al. 2019b, Lilliestam et al. 2020). Evidently, both CSP and renewables cooperation face political barriers. We believe that these barriers are surmountable and that recovery policies in the current context may help overcome them.

Sometimes, hard political reasons stand in the way of a development; this especially refers to geopolitics or security, such as energy security: if a policy is perceived as a threat to national security, it has bad chances of being implemented. As this analysis shows, this is not the case for CSP: it does not introduce exposure to any new security threats, but it helps solve the by far largest problem in a renewables-based electricity future, the balancing of fluctuating wind power and PV (see section 3.3). This was also confirmed in the interviews and the general geopolitical work in MUSTEC, in which we found no significant geopolitical or geoeconomic risks (section 2;see also Escribano et al. (2019)). This also includes a possible dependence on foreign technology, material knowhow or engineers: as vividly demonstrated in the Corona crisis, long, global supply chains may break, with potentially devastating effects, but there is a very long way between a disrupted value chain for renewable energy components and a direct threat to European electricity supply (section 3.3.5).

In the early days of the Corona crisis, the risks of global supply chains and just-in-time logistics were powerfully demonstrated to Europeans, as disinfectant and trivial products like paper facemasks were impossible to obtain – as no stocks existed and production had been outsourced to China. This situation triggered a debate on the desirability to shorten and diversify value chains and to adopt more risk averse logistic strategies: multiple sourcing, precautionary stocks and insourcing are being proposed to reduce the risks inherent to single sourcing, zero stocks and outsourcing strategies. This does not necessarily mean eradicating the latter nor fully re-localising the whole value chain, but rather diversifying to include alternatives that are geographically closer to the EU. In principle this should pose no risk at an intra-EU level. The Corona crisis – including both border closings and, especially, the temporary export bans of medical equipment – however also revealed that, when push comes to shove, the instinctive reaction of Member States was not one of solidarity and cooperation, but of isolation. This suggests that Member States are uncomfortable with relying on foreign partners, including European partners, for provision of vital goods and services; possibly, such underlying political heuristics add a piece of explanation for why no country makes use of the renewable energy cooperation mechanisms.

Further, we observe a tendency to "fossilise" renewable technologies (Raman, 2013), and specifically CSP (Carafa and Escribano, 2017; Escribano et al., 2019). Closely linked to fossilization is the abuse of the dependency narrative, which tends to value renewables exclusively as a way to get rid of fossil dependencies and vulnerabilities, and evaluating energy security impacts of renewables the same way as those of fossil fuels, although renewables and fossil fuel systems and technologies share very few characteristics. This narrow view may induce other policy barriers, like renewables mercantilism (section 2) – emphasising the job-creation narrative, and viewing domestic job creation from renewables a key imperative, also at the expense of other Member States (Lilliestam et al. 2016). This will hamper cooperation and the consolidation of grid communities on the way to a renewable future; instead, it may lead to the political instrumentalisation of electricity grids, or "grid politics" much in the same way pipeline and petro-politics has been traditionally conducted (Escribano, 2020b).

As shown above, the southern Member States, and especially Italy and Spain, are the most affected by the Corona crisis in spring 2020, having the highest death tolls but also the largest economic and social costs in terms of GDP losses and unemployment rates. This expected deterioration of economic and social conditions risks reverberating in the political arena by exacerbating populist and nationalist movements and political parties in the most affected countries. Anti-EU feelings and a North-South divide can re-emerge and intensify, re-opening the wounds of the financial crisis. This is why, from an internal EU geopolitical and geo-economic perspective, promoting renewable cooperation mechanisms and exchanges becomes more important as part of the Green Deal acceleration that is being proposed. Such acceleration is especially relevant for CSP cooperation mechanisms, which will allow Member States severely affected by the COVID-19 pandemics like Spain to benefit from green recovery plans

In short, the lack of CSP cooperation projects does not seem to be a direct result of geopolitical threats or risks, but rather of more subtle barriers that also explains the resistance to electricity interconnections within the EU, renewable power cooperation and the broader integration of its energy and electricity markets. Energy nationalism has deep geopolitical and geo-economic roots, but it is hardly technology specific. In principle, it does not pose bigger obstacles for CSP than for other energy technologies, be it renewables or fossils. In a similar vein, cooperation mechanisms should not face bigger geopolitical barriers than physical interconnections (in contrast with public acceptance, regulatory or investment barriers).

To the contrary, in the current corona-crisis context, geo-economic considerations related to energy and economic nationalism and mercantilist attitudes should lose weight in favour of more cooperative approaches. EU's CSP cooperation mechanisms are fully consistent with EU's energy transition and energy integration policy pathways. Fostering it offers significant intra-EU geopolitical externalities and co-benefits insofar it provides a counter-narrative to national-populist discourses based on anti-European feelings and exploiting the intra EU North-South cleavages inherited from the Great Recession.

4.3.2 CSP as a job engine?

If the Corona recovery programmes are to benefit CSP, it is critical to show that spending a portion of this money on CSP will not only reduce CO_2 emissions and increase the share of renewables, but also trigger growth – and especially create new jobs in Europe.

Historically, CSP has been closely related to the green growth and job creation narrative: through expansion of CSP, many have argued, will desert regions be lifted out of poverty, large amounts of new jobs will be created, and it will be a part of a general green growth strategy, in Europe and elsewhere (Caldés et al. 2009, Desertec 2009, Dii 2012, Lilliestam and Patt 2015, Trieb et al. 2015, Veum et al. 2015, Lilliestam et al. 2018, Caldés et al. 2019). In a crisis such as the present, governments will be measured against whether they manage to keep people employed, and if CSP can create jobs, it may be an attractive option for expanded policy support or for inclusion in the various national and European recovery plans.

However, there is little reason to expect that CSP on its own will create substantial amounts of new jobs. In the literature, very different estimates of the jobs created by CSP deployment can be found, also because many older estimates were derived before the CSP deployment really started in 2007 and thus cannot be based on empirical observation (Patt et al. 2011). Past estimates, based on either experiences in other sectors or in construction and early operation of single or a few of the earlies European CSP stations, range from about 10 job-years per MW in construction and manufacturing plus about 2 permanent jobs per MW in operations (ESTELA 2009), to the estimate of on average 200 job-years per MW CSP (including temporary and permanent positions, and including both direct and indirect job-creation) (Caldés et al. 2009). In MUSTEC, using the latest available data, Deliverable 9.1 finds that CSP deployment creates in Europe 39-70 full-time job-years per MW installed, depending on the scenario during the construction and operation times, including both direct and indirect employment. From these figures, 35-66 full-time job-years per MW installed would be created in Spain.

The 20-80 GW of CSP installed in the scenarios of MUSTEC (Schöniger et al. 2020) would then translate into 1.5 to 8.9 million job-years over the 30 years from 2020 to 2050; this orresponds to 25,800-185,300 permanent jobs created in Europe. In April 2020, before the lockdowns had had any mentionable effect on unemployment, some 14 million persons (6.6%) were reported to be unemployed in the EU (Eurostat 2020). About half of the installed capacity in Europe would be in Spain (Schöniger et al. 2020). This would translate into 12,000-88,000 permanent jobs created in this country. In Spain, which was still in the process of recovering from the Euro and financial crises a decade ago, the unemployment was 14.8%, or 3.4 million persons. Hence, , the up to 185,000 "permanent" jobs would be a welcome addition, but it would hardly make a dent in the statistics: this number corresponds to 1.3% of all unemployed in Europe, or 3% of the currently unemployed in Spain.

Further, not all associated jobs will arise in Spain or even in Europe. In the last years, a Chinese CSP industry has arisen, driven by a national support programme for CSP. As the European industry suffered from a lack of new projects in the last 5 years and was largely unable to break into the Chinese market, the current global CSP industry is dominated by Chinese firms. This dominance is particularly strong in the tower segment, where Chinese companies have successfully finished a number of projects in the last 2 years: all but two completed towers were Chinese. The remaining two were led by Spanish SENER (Noor III, Morocco) and US Brightsource (Ashalim B); Brightsource currently leads construction of the tower at Noor Energy 1 in Dubai. Of the two completed trough stations in China, one (Delingha) was mainly built by Spanish partners (among others IDOM, TSK, Rioglass) and the other (Royal Tech Urat) had significant Spanish input and was built with European-designed components manufactured in China. All other trough stations finished in 2015-2019 were built with only or mainly Spanish CSP-specific equipment and knowhow (Lilliestam et al. 2019a, csp.guru 2020, Lilliestam et al. 2020).

Hence, if the Chinese companies survive the expected crunch-phase after the cancellation of the national CSP support in China in 2021, Chinese companies are going to be serious competitors for its Spanish counterparts if a European CSP expansion is based on tower technology. If, on the other hand, the expansion is mainly parabolic trough stations, there are good chances that Spanish firms will supply, construct and operate the stations, and that most jobs will indeed arise in Spain and Europe.

Still, the job creation from CSP will be modest, even in the best case. However, the Corona recovery programmes, if successfully spent on green technology including renewables, will trigger a fast forward trend in already existing energy pathways: many countries have 100% renewables targets for 2050, and many have highly ambitious targets already 2030 – including the Spanish target of 74% renewable electricity (Lilliestam et al., 2019). If things go well, the Corona recovery programmes could give a substantial push to renewables, and especially the strongly dominant sources wind power and solar PV. In these sectors, job creation can be much larger: already today, some 100,000 Europeans work in the PV sector and over 300,000 in the wind power sector (IRENA 2019). Only if the rise in fluctuating renewables is accompanied by an increase in flexible supply can the wind power and solar PV deployment be successful. Hence, the most important job-creating effect of CSP may not be in the CSP sector itself, but in the wind power and PV sector growth enabled bythe deployment of dispatchable, flexible CSP.

5 SUMMARY

Concentrating solar power (CSP) is one of the few renewable power technologies capable of generating dispatchable electricity on demand. As such, it could have a key role to play in the transition of the European power system, both to supply bulk renewable power and to balance fluctuating wind power and solar PV. Despite this, CSP is a non-issue on most European policy agendas.

We show that although CSP has many geopolitical advantages, including "hard politics" issues like reduced import dependency, it is hardly even known in geopolitical circles. We find that whereas renewables have entered the energy geopolitical thinking in Europe, CSP and the cooperation mechanisms have not. To some extent, this is because CSP is still a small and rather immature technology, and no European country except Spain has deployed commercial-scale CSP; we however also show that CSP has become "fossilised", and is judged with the same criteria as fossil fuels, following the same well and pipeline logics, in a competitive setting between countries. This would further hamper the use of the cooperation mechanisms.

This absence of CSP, with or without cooperation mechanisms, leads Europe to miss an opportunity to improve its energy security. In practice, energy security is primarily about the uninterrupted supply of energy to customers. For this purpose, CSP has a vital role to play, as it is one of the few, if not the only, dispatchable renewable power technology that can be scaled up in Europe: CSP can thus be used to stabilise the system as the shares of fluctuating renewables increase. As these fluctuations are the by far largest threat to a renewables-based power system, and especially as CSP would not add any further mentionable threats or vulnerabilities, CSP would increase the energy security of the European power system compared to any other climate-neutral configuration without CSP.

The Corona crisis has had devastating impact across Europe, and especially in southern Europe, both the virus itself and the economic impacts of the lockdown and isolation measures. Across Europe, as well as in Brussels, governments present recovery programmes of unprecedented size, and herein lies a chance for a green recovery. We show that CSP, both for domestic use and for trade under the cooperation mechanisms, may have an important role to play, in two ways. First, through the jobs triggered directly in the CSP industry, in which Spain remains world-leading: here, a CSP expansion as proposed in MUSTEC, could lead to the creation of 25-100,000 jobs. Second, and even more importantly, adding dispatchable CSP to the European power system would allow for higher shares of fluctuating wind power and solar PV – and hence allowing a rapid scale-up of these technologies, which would very likely create new jobs of even larger magnitude than the CSP jobs alone.

In sum, we show that although CSP does not play a big role in European energy and geopolicy at the moment, it has a key role to play to secure the European power supply in a renewables-based future, thereby contributing to green growth and job-creation in southern Europe and across the continent. While no significant intra-EU geopolitical shifts are at stake regarding CSP cooperation mechanisms, it concludes that the geopolitical barriers that prevent the integration of CSP and cooperation mechanisms into European electricity markets and regional energy integration itself can no longer be justified under the COVID-19 crisis. If geo-economic considerations based on energy and economic nationalism and mercantilist attitudes are to lose weight in favour of more cooperative and cohesive approaches, it is concluded that EU's CSP cooperation mechanisms are fully consistent with EU's energy transition and energy integration policy pathways. Furthermore, they offer significant intra-EU geopolitical externalities by providing a counter-narrative to national-populist and anti-European discourses exploiting EU's North-South cleavages. This deliverable argues in favour of mainstreaming and fast-tracking CSP cooperation mechanisms as an internally consistent geopolitical response to the COVID-19 crisis by the EU.

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Who We Are

The MUSTEC consortium consists of nine renowned institutions from six European countries and includes many of the most prolific researchers in the European energy policy community, with very long track records of research in European and nationally funded energy policy research projects. The project is coordinated by Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas-CIEMAT.

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